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Landscape structural changes between 1950 and 2012 and their role in wildlife–vehicle collisions in the Czech Republic

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ABSTRACT

Roadway safety is a major concern for the general public and understanding factors that affect wildlife–vehicle collisions (WVCs) which is an important area in road ecology research. Even though many studies on landscape change have been conducted worldwide in the last 20 years, as well as present work focused on the effects of selected landscape structural characteristics on WVCs, an effort to examine the effects of historical changes in landscape structure on WVCs is missing. The main goal of this study is to analyse the role of the spatio-temporal changes in landscape structure between 1950 and 2012 for WVCs in the Czech Republic. Aerial photos from 1950 and 2012 were used to analyse changes in landscape structure based on the use of a Geographic Information System (GIS). The analyses were conducted in 52 hotspots (areas with the highest density of WVCs per square kilometre in the Czech Republic). The results showed that each hotspot has had a relatively high reconfiguration of the landscape structure, which has had a crucial influence on the given habitats. In some hotspots the level of unstable land cover patches between 1950 and 2012 was more than 80% of the total area and the average of the unstable patches for all 52 hotspots was 53.23%. The identification of transformation trajectories is also very important, i.e. on the one hand huge decreases of grassland, and on the other hand increasing successional areas, arable land, and built-up area, as well as areas of transport infrastructure. The landscape pattern was dramatically changed, too. A fine, heterogeneous mosaic of small patches (with many possibilities for migration pathways) was converted into large, homogeneous blocks. In some cases a highly complex structure was created, where two or more roads follow similar directions. All this activity has resulted in low landscape permeability and a higher risk of WVCs. A retrospective view on landscape can help to correct this state of affairs.

1. Introduction

Among the most negative effects of traffic on wildlife are direct taking of land and transformation of natural biotopes (Iuell et al., 2003; Fahrig and Rytwinski, 2009; Anděl et al., 2010), fragmentation of natural biotopes (Hlaváč and Anděl, 2001; Iuell et al., 2003; Anděl et al., 2010), migration impediment (Hlaváč and Anděl, 2001; Iuell et al., 2003; Hlaváč, 2005; Anděl et al., 2010; Polak et al., 2014) and mortality resulting from roadkill (Bíl et al., 2016). Much research effort has been spent on investigating wildlife–vehicle collisions (WVCs; e.g. Montgomery et al., 2012; Meisingset et al., 2013) and their basic variables, such as speed, traffic intensity, time, and location (Gibbs and Shriver, 2002; Van Langevelde and Jaarsma, 2004; Bissonette and Kassar, 2008; Benítez-López et al., 2010; Gkritza et al., 2010; Found and Boyce, 2011; Neumann et al., 2012; Ascensão et al., 2013; Kušta et al., 2014a; Polak et al., 2014). However, only limited research has been carried out in the field of long-term functional changes of landscape structure in the immediate vicinity of road infrastructure and its impact on the numbers of WVCs. Previous similar research has mostly been focused on the spatial and temporal evaluation of WVCs in present time (Markolt et al., 2012; Wang et al., 2013; Kušta et al., 2014a,b), whereas a retrospective view is lacking. In the Czech Republic the rapid increase in transport infrastructure, and particularly in line constructions such as roads, motorways and railway networks, is significantly reducing the connectivity of the landscape for wildlife (Hlaváč and Anděl, 2001). Nevertheless, the Czech Republic is still relatively unfragmented (Anděl et al., 2010). However only 40 percent of the

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total Czech motorway network are permeable for roe deer and wild boar, and only 30 per cent are permeable for red deer, elk, and large carnivores (Hlaváč, 2005).

1.1. Mortality of wildlife on roads

There is a huge and rapidly expanding array of literature dealing with WVCs and with factors influencing roadkill occurrence patterns and frequencies (Ford and Fahrig, 2007; Fahrig and Rytwinski, 2009; Grilo et al., 2009; Gunson et al., 2012; Markolt et al., 2012). In the Czech Republic the most treated wild animals by road transport and estimated number of WVCs during the study period from 2006 to 2011 according to Mrtka and Borkovcová (2013) are: *Lepus europaeus* (144,000 road kills), *Capreolus capreolus* (129,000 road kills), *Erinaceus* spp. (32,000 road kills), *Martes* spp. (19,000 road kills), *Vulpes vulpes* (17,000 road kills), and *Sus scrofa* (17,000 road kills). Based on these results, we assumed that the data from the Police of the Czech Republic (2014), which we analysed, mainly represent collisions with *Capreolus capreolus* and *Sus scrofa*. Wild animals such as *Lepus europaeus* or *Erinaceus* spp. are not involved in the police database as they do not have the necessary body size to cause property damage of 100,000 CZK or more in collisions.

1.2. Landscape changes between 1950 and 2012 in the Czech Republic

Landscapes are characterised by continuous and dynamic change, which may be expressed by changes in landscape structural characteristics (Kienast, 1993; Ihse, 1995; Lipský, 1995; Cousins and Ihse, 1998; Fjellstad and Dramstad, 1999; Cousins, 2001; Skaloš et al., 2014). Recently, the issue of monitoring landscape changes has resulted in a number of investigations which have yielded considerable information about landscape transformation, particularly at the national level (Kienast, 1993; Lipský, 1995; Ihse, 1995; Cousins and Ihse, 1998; Fjellstad and Dramstad, 1999; Cousins, 2001; Williams, 2003; Bender et al., 2005; Brabyn, 2005; Calvo-Iglesias et al., 2009; Sklenička and Molnárová, 2010; Abd El-Kawy et al., 2011; Campos et al., 2012; Delahunty et al., 2012; Echeverría et al., 2012; Fox et al., 2012; Plieninger, 2012). In particular, monitoring changes in land use/land cover (LU/LC) has played a key role in how scholars assess changes in landscape (Turner et al., 2007). The analysis of LU/LC change plays an essential role in understanding a great variety of phenomena in several research fields (Lipský, 2000; Olah and Boltižiar, 2009; Olah et al., 2009; Gerard et al., 2010), even in the relatively new field of Road Ecology.

Besides the ‘typical’ landscape change works (e.g. Hooke and Kain, 1982; Bürgi and Russell, 2001; Bender et al., 2005; Pelorosso et al., 2009; Kanianska et al., 2014), there are studies that address various additional landscape change issues (Falt’an et al., 2011; Šímová and Gdulová, 2012; Skaloš et al., 2012; Latocha, 2013; Sklenička et al., 2014), or represent multidisciplinary studies applying other disciplines in the study of landscape change, e.g. historical geography, archaeology, sociology, political economy, etc. (e.g. Rindfuss et al., 2004; Hersperger et al., 2010; Gojda and Hejcman, 2012; Vojta and Drhovská, 2012). There are also many interesting studies focusing generally on the analysis of spatial changes in the landscape (e.g. Seabrook et al., 2007; Huzui et al., 2012; Spanò and Pellegrino, 2013; Khromykh and Khromykh, 2014). The rate of change varies in accordance with the fluctuations in natural and anthropogenic processes (Skånes, 1996). Natural conditions are the most important factors that set limits on land utilization (Havlíček and Chrudina, 2013; Druga and Falt’an, 2014). There are a number of interesting studies that deal with the analysis of factors that influence changes in the structure of the landscape. E.g. Geist and Lambin (2002) distinguishes explanatory variables that represent proximate causes (more direct), and underlying driving forces (more abstract and acting indirectly) that are generally distinguished in landscape ecology. There are several crucial studies dealing with the analysis of driving forces of landscape change, distinguishing between natural and cultural factors (Bürgi and Russell, 2001; Bürgi et al., 2004; Hersperger et al., 2010; Skokanová et al., 2016).

The Czech landscape has experienced a dynamic history full of dramatic changes. From the modern perspective, the end of WWII is taken as a turning point for the Czech landscape (Skaloš and Kašparová, 2012). After 1948, when the Communist Party took power in the former Czechoslovakia, dramatic changes in the cultural landscape were characterised by large-scale Soviet-style farming with an emphasis on intensification. Doucha (2001) mentions the following key events after WWII: 1) The displacement of the German population from the Sudety region and the subsequent resettlement by Czechs (1945–1948); 2) The first phase of collectivisation (1950s); 3) The second phase of collectivisation (1970s); 4) Land consolidation in cadastral areas (1970s–1980s). The first and second phases of collectivisation are characterised as: i) parcels of arable land being unified; ii) meadows, pastures, and other non-arable land between or next to arable land being converted into arable land; iii) linear or scattered elements of greenery, as well as unpaved field roads, being removed as a result of the extensification of agricultural land.

1.3. Landscape memory

Information on LU/LC is the basis on which past and present human interactions and the impacts of such interactions on natural resources and the environment can be understood. Sádlo (2004) states that landscape memory is the ability to regenerate its former state. Sklenička (2003) defines landscape memory as the ability to retain some landscape attributes, but also as the ability to regenerate these attributes. Landscape memory has five aspects: relief, locality, land cover, land use, and the human factor (Cílek, 2002). Over centuries wild animals had created networks of migration corridors in the open landscape that they used for their movement. Due to human activity, the surroundings of migration corridors and the migration corridors themselves have changed drastically in recent decades. So the question is whether these changes were projected in animal behaviour and movement patterns? Or is there something like “animal migration memory”, meaning wildlife used the same migration corridors through generations, regardless of landscape change.

1.4. Migration potential

Migration potential (MP) is defined as a probability of migration profile functionality. It expresses preconditions of a profile for allowing migration and is defined by two levels: ecological migration potential (MPE) and technical migration potential (MPT). Total migration potential is a product of the two components ($MP = MPE \times MPT$) (Anděl et al., 2005). Ecological migration potential (MPE) is a model of acceptability of ecological conditions for migration in the area. It is defined by the characteristics of the migration route itself as well as the ecological characteristics of the near and wider surroundings. It mainly refers to a combination of auxiliary elements (suitable habitats, scattered greenery, guiding structures, watercourses, etc.) and disruptive elements (transport, settlement, industry, mining of raw materials, etc.). Technical migration potential (MPT) is a model expression of the probability with which a proposed technical solution enables full migration of animals. It is defined by the type of technical solution, the size of migration objects and the state of complementary